Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 46 (2015) 973 – 980

Procedia Computer Science

International Conference on Information and Communication Technologies (ICICT 2014)

Techniques to Enhance the Quality of Service of Multi hop Relay Networks

Arthi M, Arulmozhivarman P, Vinoth Babu K*, Ramachandra Reddy G, Barath D

School of Electronics Engineering, VIT University, Vellore 632 014, India

Abstract

Broadband internet access through the user equipment has become the hot research topic. The shadowing and multipath issues restrict the high performance nature of 4G cells. In Multi hop Relay (MHR) networks, Relay Stations (RS) are introduced to improve coverage and capacity of the system. There exist some issues like path selection and RSs deployment, which severely affects the Quality of Service (QoS) of the system. In this paper, to improve the QoS of MHR networks, Load Aware Routing Metric (LARM) based path selection and a low complex Burst Profile (BP) based RS deployment schemes are discussed.

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)

Keywords: Worldwide Interoperability for Microwave Access (Wi-MAX); BP; LARM; Link Efficiency (LE); Downlink (DL).

1. Introduction

Present Broadband Wireless Access (BWA) technologies demand for high data rate with high QoS[1]. Wi-MAX and Long Term Evolution-Advanced (LTE-A) are the cost effective alternates to Digital Subscriber Line (DSL) broadband[2]. To improve the network throughput and the coverage, 3GPP LTE-A and IEEE 802.16j working groups have developed MHR architecture. This architecture is expected to reduce the deployment and maintenance cost of the Base Station (BS). Wi-MAX and LTE networks use Orthogonal Frequency Division Multiple Access (OFDMA) in the DL[3]. The radio resources are scheduled by the BS to each Mobile Station (MS) and RS. This architecture uses two different links namely radio links and access links. The links originating or terminating at MS are access links

* Corresponding author. Tel.: +91-999-431-1391.
E-mail address: vinothbab@gmail.com

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)
doi:10.1016/j.procs.2015.01.007

and the links between pair of RSs or between BS and RS are radio links. Each MS in a particular MHR cell may experience different DL paths. Finally the MS has to get service from only one path. Selecting an improper path leads to loss in the throughput. Many path selection schemes discussed in the literature do not consider the link overloading issue[4-8]. In[9], it has been proved that the LARM algorithm outperforms the conventional algorithms like Radio Resource Utilization Index (RRUI) by considering the link overloading issue. This paper considers the performance of the LARM algorithm as the benchmark and also highlights the improvements to be considered for the existing LARM algorithm. To improve the network throughput further, optimal BP based RS deployment scheme is also highlighted in this paper.

The rest of the paper is arranged as follows. The overview of IEEE 802.16j BP is discussed in section 2. The network model for path selection and the LARM based path selection are discussed in section 3 and 4 respectively. Section 5 discusses about the BP based number of RS identification scheme. Section 6 discusses the simulation results and section 7 concludes the paper.

Nomenclature

r	coding rate
R_p	repetition rate
M_{MS}	number of MSs in the cell
M_p	number of DL paths
T	Traffic
c	Link cost
C	Path cost

2. Overview of IEEE 802.16j Burst Profiles

Table 1. BPs supported in IEEE 802.16j

BP:ID	Modulation (m)	Coding scheme	Code Rate(r)	Repetition rate (R_p)	LE
1	QPSK(2)	CC/CTC	1/2	6	1/6
2	QPSK(2)	CC/CTC	1/2	4	1/4
3	QPSK(2)	CC/CTC	1/2	2	1/2
4	QPSK(2)	CC/CTC	1/2	1	1
5	QPSK(2)	CC/CTC	3/4	1	3/2
6	16-QAM(4)	CC/CTC	1/2	1	2
7	16-QAM(4)	CC/CTC	3/4	1	3
8	64-QAM(6)	CC/CTC	1/2	1	3
9	64-QAM(6)	CC/CTC	2/3	1	4
10	64-QAM(6)	CC/CTC	3/4	1	9/2
11	64-QAM(6)	CTC	5/6	1	5

During the resource allocation phase, MHR-BS is responsible for allocating the suitable BPs to RS and MS. The list of BPs supported in IEEE 802.16j standard is shown in Table 1. This standard mainly uses two different Error Correction codes like Convolutional Codes (CC) and Convolutional Turbo Codes (CTC) with different code rates. It also uses the modulation schemes like Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) with sizes M=16 and 64[9]. From table 1, it is clear that the lower BPs have low LE and the higher BPs have higher LE. The MSs and RSs experiencing poor signal quality will be scheduled with lower BPs and the MSs and RSs experiencing better signal quality will be scheduled with higher BPs[10]. The introduction of RSs in

MHR network reduces the distance between the stations and enhances the overall throughput. The BP is allocated based on the received SNR which is not shown in table 1.

Hop Count is another parameter used in the literature for path selection[5]. Some of the algorithms suggest selecting a path with minimum hop count. But the minimum hop count will increase the distance between the stations, which in turn makes the system to use lower BPs. This causes reduction in the network throughput. In[9], the authors suggest LE as the suitable metric for path selection.

3. Network Model

A typical MHR network is shown in Fig. 1 (a). From Fig. 1 (a), it is clear that MS has three different paths. Path 2 is the direct path (MHR-BS to MS) and path 1 and path 3 are indirect paths. Each indirect path may have multiple links. For example, path 1 has four links and path 3 has two links.

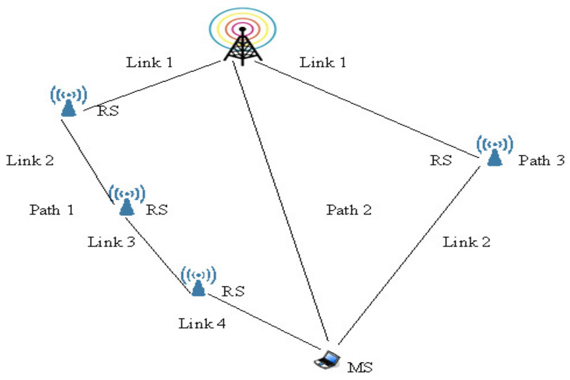

Fig. 1 (a). MHR Networks

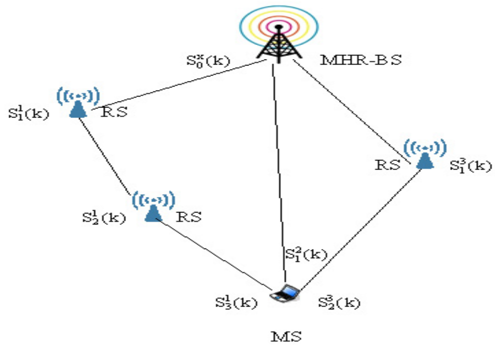

Fig. 1 (b). Each path indicated by the stations

We define the following variables to explain the proposed LARM path selection algorithm. M_{MS} is the number of MSs in the cell. $MS(k)$ represents k^{th} MS in the cell, where k=1,2… M_{MS}. M_p is the number of DL paths. $P^l(k)$ is the l^{th} path from MHR-BS to k^{th} MS, where l=1,2… M_p. $N^l(k)$ is the length of l^{th} path. $P^l(k)$ can be represented as the sequence of stations[9].

$$P^l(k) = \left\{S_0^l(k), S_1^l(k) \ldots S_{N^l(k)}^l(k)\right\} \tag{1}$$

where $S_0^l(k)$ is the MHR-BS, $S_{N^l(k)}^l(k)$ is the required k^{th} MS and the others are intermediate RSs. $L_{i,i+1}^l(k)$ represents the link between the stations $S_i^l(k)$ and $S_{i+1}^l(k)$ of l^{th} path. The superscript indicates path index and the subscript indicates station index. Fig. 1 (b) explains how paths can be represented by the sequence of stations.

LE for a particular BP can be calculated as[9],

$$LE_{i,i+1}(k) = \frac{m.r}{R_p} \tag{2}$$

where $m = \log_2 M$. The LE calculated in (2) is for one subcarrier. As per IEEE 802.16j standard there exist 48 data subcarrier in a time slot[11]. The total amount of traffic (in bytes) an OFDMA slot can transmit in a link is given as,

$$T_{i,i+1}(k) = \frac{48.LE_{i,i+1}(k)}{8} \quad (3)$$

$$T_{i,i+1}(k) = 6.LE_{i,i+1}(k) \quad (4)$$

Link cost is the ratio between link load and LE. The cost of the link between the stations i and i+1 in the path l for k^{th} MS is given as[9],

$$c^{l}_{i,i+1}(k) = \frac{D^{l}_{i,i+1}(k)}{6.LE^{l}_{i,i+1}(k)} \quad (5)$$

where $D^{l}_{i,i+1}(k)$ is the traffic load (in bytes) of the link between the stations i and i+1 in the path l. The cost of l^{th} path is given as,

$$C^{l}(k) = \sum_{i=0}^{N^{l}(k)} c^{l}_{i,i+1}(k) \quad (6)$$

4. LARM Path Selection Algorithm

The following steps are executed in sequence to find the optimal path.

Step 1: If $\{\text{DL Traffic of MS(k)}\} < \{\text{available resources of MHR} - \text{BS}\}$
Then do
for l=1, 2… M_p
for i=0,1,.. $N^{l}(k)$
Compute $C^{l}_{i,i+1}(k)$ using equation (5)
Compute $C^{l}(k)$ using equation (6)
Step 2: Select path $P^{l}(k)$ with minimum $C^{l}(k)$.

This algorithm is named as RRUI algorithm which is proposed in[4]. Consider Fig. 2, where MS (2) has three DL paths. Assume MS (1) is already supported by RS (1). MS(2) has one direct path and two indirect paths like MHR-BS- RS(1)- MS(2) and MHR-BS-RS(2)-MS(2). Also assume MS (2) has minimum cost path through RS (1). Since RS (1) already supports MS (1), the link between MHR-BS and RS (1) suffers from link overloading problems. This reduces the throughput of MS (1) and MS (2). Link overloading issue becomes very severe, when the traffic load is more. The reduction in data rate also introduces unnecessary delay in transmission. This affects the QoS of time bounded application. In LARM scheme, RRUI algorithm is modified in such a way that MHR-BS will select next minimum cost path to provide service for MS (2). If again there exist a link overloading issues BS has to go for next minimum cost path. In this case MS (2) has to get service from RS (2) instead of RS (1). It should be also noted that RS (2) should not suffer from link overloading problems. The following steps are included to modify the RRUI algorithm to get LARM algorithm.

Step 1: Use RRUI Algorithm and calculate cost of each DL path. Identify minimum cost path.

Step 2: Verify all the links in the minimum cost path satisfies the following condition.

If $\{\text{Total traffic through the link } L^{l}_{i,i+1}(k)\} < \{\text{Capacity of the link } L^{l}_{i,i+1}(k)\}$

Then

Use minimum cost path as optimum path.

else

Repeat step 2 for the next minimum cost path.

Step 3: Repeat step 2 until the identification of optimum path.

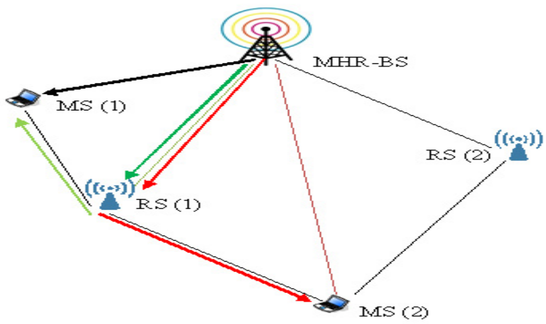

Fig. 2. Link overloading problem

5. BP Based Optimum RSs Identification Scheme

Even though more number of RSs improve the coverage and capacity, they may introduce radio resource management problems[12]. More number of RSs will introduce more number of DL paths for each MS in the cell. More number of DL paths will introduce path selection problems like unnecessary delay in path selection. The delay is the unwanted result in time bounded applications. The original LARM scheme does not discuss about the selection of optimum number of RSs in a cell. This is an open issue where many researchers are still working. To offer better service even for cell edge users, BS has to use higher BPs which will increase the number of RSs. The present proposed scheme solves the tradeoff between network throughput and the number of RSs for the cell edge MSs. This scheme is explained with an example in section 6.

6. Simulation Results and Discussion

We use matlab tool to test the performance of the proposed schemes. The first part of this section concentrates on the LARM path selection scheme. For simulation, we use center excited MHR-BS which is assumed to offer a coverage for 17 Km. To improve the coverage and capacity, we use 6 Fixed Relay Stations (FRS) within the cell. It is also assumed that FRS are deployed on the vertices of the cell. In this work, we have not concentrated on optimal BS and RS deployment. It is also assumed that the RSs labelled from 1 to 6 are using the BPs like 5, 4,6,7,4 and 6. In this work, we have displayed only the results of two scenarios like with and without link overloading problem. For each scenario, we have taken three cases like without using RS, path selection with RRUI scheme and path selection with LARM scheme. It is also assumed that MSs are uniformly distributed throughout the cell.

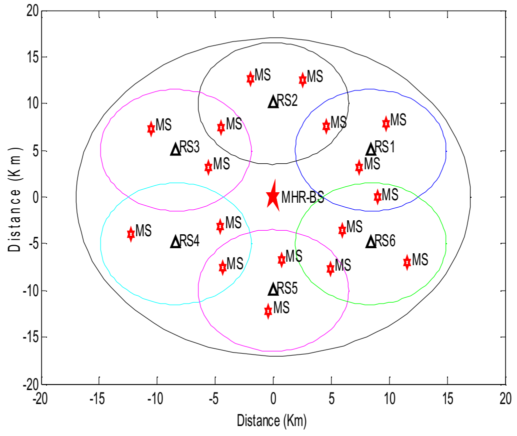

Fig. 3 (a). Scenario 1: No link overloading

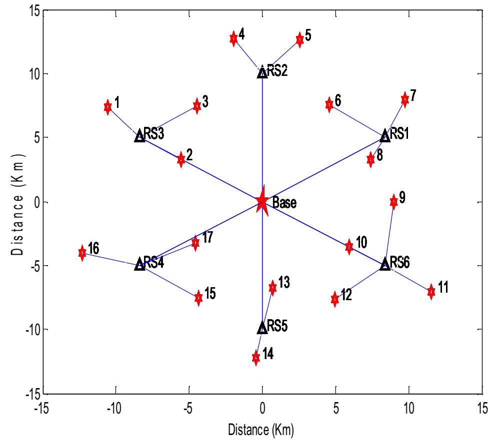

Fig. 3 (b). Different MSs getting service from different FRS in scenario 1

In Fig. 3 (a), the scenario is set in such a way that there is no link overloading issue. The path allocated for each MS with RRUI and LARM schemes are shown in Fig. 3 (b). Since each RS takes care of sufficient number of MSs, the performance of RRUI and LARM becomes exactly same. This scenario is repeated by different number of MSs at random locations in the cell. The simulation results prove that the performance of RRUI and LARM are almost same when there is no link overloading issue. For 100 different simulations, the RRUI and LARM scheme offers an average net throughput of 9.5 Mbps whereas the system with no relay offers only 4.5 Mbps. This result is displayed in Fig. 4 (a).

In scenario 2, we have introduced link overloading issue by deploying multiple MSs near a particular RS. One such test case is shown in Fig. 5 (a). From Fig. 5 (b), it is clear that there occurs link overloading issue from RS3 to MS6 and MS7. Using LARM scheme, BS schedules the service for these MSs from RS3 to RS. By considering the link overloading issue, the simulations are repeated for 100 different times and the average network throughput results have been displayed in Fig. 4 (b). From the results, it is very clear that LARM scheme offers a net throughput of 10.6 Mbps, whereas the RRUI scheme offers only 9.5Mbps.

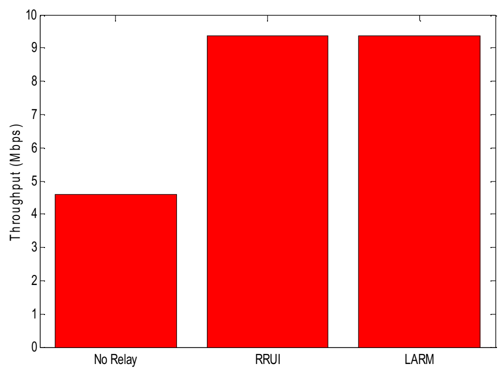

Fig. 4 (a). Throughput comparison between LARM, RRUI and No relay cases for scenario 1 with no link overloading

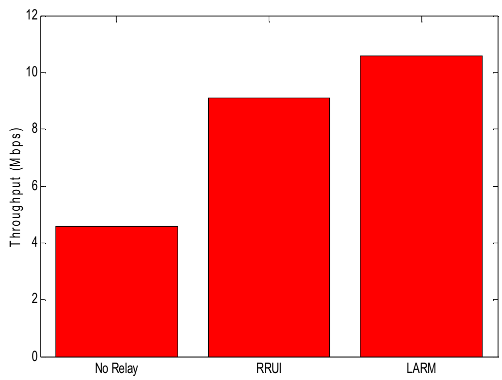

Fig. 4 (b). Throughput comparison between LARM, RRUI and No relay cases for scenario 2 with link overloading issue

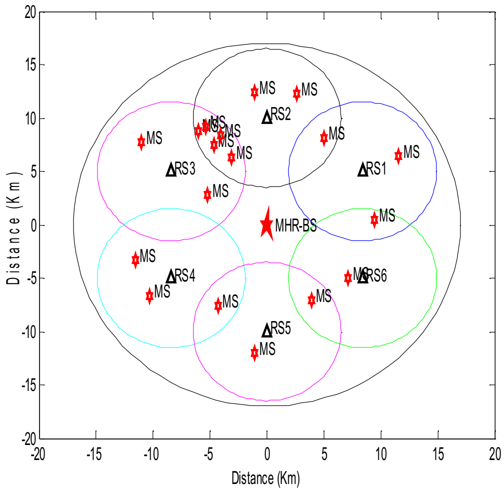

Fig. 5 (a). Scenario 2: More MSs are located in RS3 than other RSs

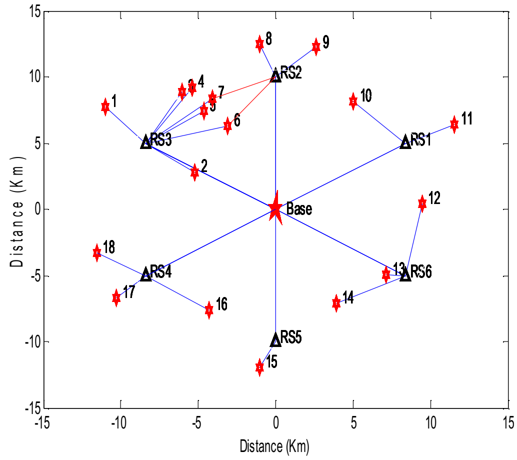

Fig. 5 (b). Service of few MSs are transferred from RS3 to RS2 based on LARM

To simulate the proposed scheme of identifying the optimum number of RSs, we have used IEEE 802.16 macro cell suburban path loss model[13]. This model basically uses a hilly terrain with moderate to heavy tree densities. There will be heavy path loss because of heavy scattering. So very small distance from the MHR-BS will have huge path loss. The path loss is given as,

$$PL_{802.16}(d)[dB] = PL_{free}(d_0) + 10\eta \log_{10}\frac{d}{d_0} + k_f + k_{RX} \quad ; d > d_0 \tag{7}$$

where d_0 is reference distance, $PL_{free}(d_0)$ is the free space path loss at reference distance d_0, d is the distance between the communication stations, k_f is the correlation coefficient for the given carrier frequency, k_{RX} is the receive antenna correlation coefficient and η is the constant.

For simulations, the reference distance is taken to be 100 meters. The transmitter and receiver antenna heights are assumed to be 30 and 2 meters respectively. The carrier frequency is chosen to be 2 GHz. A small cell with 450 meters coverage is considered for the simulation. Here 3 different cases are considered for comparison. Case 1 and case 2 deals with BP 7 and BP 9 and case 3 deals with the proposed solution. From IEEE 802.16j BP list, it is identified that BP7 and BP9 can be used when the minimum received SNR is of 17.63dB and 24.15 dB respectively. In case (1), the received SNR reaches to 17.63 dB approximately at 200 meters. To enhance the coverage and capacity a RS is deployed at 200m. Again the received SNR reaches to 17.63 dB at 320 meters. Thus another RS is deployed at distance of 320 meters from BS. Two RSs are required to cover 450 meters with BP 7. This increases the average network throughput to 16 Mbps. In case (2) the received SNR reaches 24.15 dB at 140, 230, 320 and 420 meters. To cover entire 450 meters with BP 9, we need 4 RSs. This increases the average throughput to 26 Mbps. But this needs more RSs. The number of RSs not only increases the throughput but also the deployment and maintenance cost. To cope up the trade off, one RS can be placed at 140 meters which can use BP 9. Then two RSs can be deployed at 270 and 380 meters with BP 7.This needs only 3RSs, but it can offer net throughput of approximately 24 Mbps which is nearer to case (2). Three different cases & the corresponding throughput values are displayed in Fig. 6(a) & 6 (b) respectively.

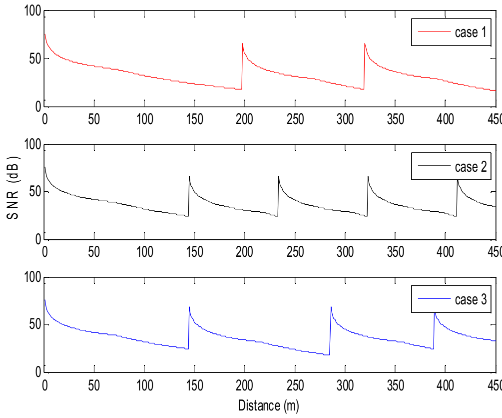

Fig. 6 (a). SNR (dB) vs. Distance (m) for three different cases

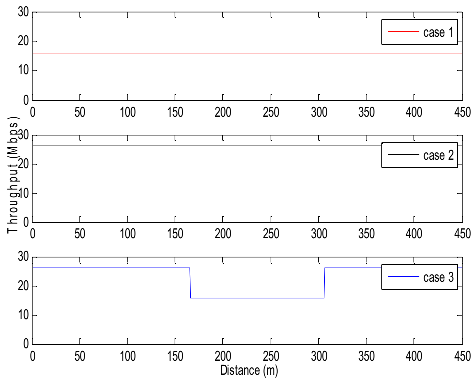

Fig. 6 (b). Throughput (Mbps) vs. Distance (m) for three different cases

7. Conclusion

This paper talks about the LARM based path selection and a low complex BP based optimum number of RSs identification schemes. The simulation results prove that LARM scheme offers an average network throughput improvement of 10.37% over RRUI scheme. The realistic impairment like link error and channel information feedback delay has to be considered for future work. It is also proved that BP based number of RSs identification scheme offers maximum throughput by using less number of RSs. This scheme has been developed only for cell edge MSs. It has to be modified for all MSs in the cell.

References

1. Sesia S, Toufik I, Baker M. *LTE-The UMTS Long Term Evolution from theory to practice*, 2nd ed. United Kingdom: John Wiley & Sons Ltd.; 2011.
2. WiMAX Forum. Mobile WiMAX - Part I: A Technical Overview and Performance Evaluation; 2006.
3. Vinoth Babu K, Ramachandra Reddy G, Yeswanth Reddy G, Rahul Krishna K. Dynamic Subcarrier Spacing (DSS) for Wi-MAX based Type I Relay Networks. *Australian Journal of Basic and Applied Sciences* 2013; 7:65-71.
4. Wang S-S, Yin H-C, Tsai Y-H, Sheu S-T. An effective path selection metric for IEEE 802.16 based multi-hop relay networks. *In: Proceedings of the IEEE symposium on computers and communications* 2007; 1051-6.
5. Perkins CE, Bhagwat P. Highly dynamic destination sequenced distance-vector routing (DSDV) for mobile computers. *In: Proceedings of the ACM conference on communications architecture, protocols and applications* 1994; 234-44.
6. Koskal CE, Balakrishnan H. Quality-aware routing metrics for time-varying wireless mesh networks. *IEEE J Select Areas Commun* 2006; 24: 1984-94.
7. Ann S, Lee KG, Kim HS. A path selection method in IEEE 802.16j mobile multi-hop relay networks. *In: Proceedings of the IEEE second International conference on sensor technologies and applications (SENSORCOMM)* 2008: 808-812.
8. Se-Han Kim, Se-Jin Kim, Jae-Yong Lee, Byung-Chul Kimm. Energy efficient path selection scheme for OFDMA-based two-hop cellular systems. *Journal of Systems Architecture* 2013; 59:947-952.
9. Sheng-Shih Wang, Chan-Ying Lien, Wen-Hwa Liao,Kuei-Ping Shih.LASER: A load-aware spectral-efficient routing metric for path selection in IEEE 802.16j multi-hop relay networks. *Computers and Electrical Engineering* 2012; 38:953-962.
10.Jau-Yang Chang, Ya-Sian Lin. A clustering deployment scheme for base stations and relay stations in multi-hop relay networks, *Computer and Electrical Engineering* 2014:40:407-420.
11.IEEE Standard 802.16 Working Group. Standard for local and metropolitan area networks, part 16: air interface for broadband wireless access systems; 2009.
12.Deepak RD, Deshmukh PR. Relay node placement for multi-path connectivity in heterogeneous wireless sensor networks. *In: Procedia Technology* 2012; 4:732-736.
13.Cho YS, Kim J, Yang WY, Kang CG.*MIMO-OFDM Wireless Communications with Matlab*, 1st ed. Singapore :John Wiley & Sons (Asia) Pvt. Ltd.; 2010.